International Journal of Applied Engineering and Technology ISSN: 2277-212X (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jet.htm
2015 Vol. 5 (1) January-March, pp.78-83/Suman
Research Article

THERMAL CONDUCTIVITY MEASUREMENT OF POWDER MATERIAL AND ITS OPTIMUM APPLICATION FOR ENERGY EFFICIENT COLD STORAGE

***Suman B.M.**
CSIR- Central Building Research Institute, Roorkee, Uttarakhand 247667, India
**Author for Correspondence*

ABSTRACT
The paper describes the measurement technique of thermal conductivity of powdered material and computation of optimum thickness to satisfy the value of overall thermal transmittance recommended by Indian Code of standard IS: 661 for making cold storage energy efficient. The computational method of optimum thickness has been discussed for both powder and solid thermal insulation for temperature range between – 4^o C to 2^o C and 2^o C to 10^o C. The ranges of optimum thickness of powdered materials are compared. The result of the study shows that new powder insulation thickness is reduced approximately by half of the conventional powder insulation such as, rice husk or saw dust for maintaining same range of temperature.

Keywords: *Guarded Hot Plate Apparatus, Energy Efficient, Overall Thermal Transmittance, Powder Thermal Insulation, and Thermal Efficiency*

INTRODUCTION
Conventional materials such as rice husk and saw dust are used in potato cold storage from last more than thirty years. Similarly other powder thermal insulation such as loose vermiculite and expanded Perlite can also be used in cold storage with suitable thicknesses for maintaining temperature range between – 4 ^{o}C to 10 ^{o}C with energy saving points of view. The application of powdered material in the cold storage is made by filling in between double wall or double roof. Numbers of studies by (Demirboga and Gul, 2003) and (Khan *et al.*, 2008), have been made on effect of loose powder insulation materials on thermal performance of their products. The optimum thicknesses of these materials were used to fulfil the limit of U- value recommended by Indian Code (IS: 661, 2000). The choice of an insulating material for any particular application is decided by its thermal efficiency. A variety of insulation materials described by (Suman and Suman, 2012), such as cellular plastic, fibrous materials, in the form of slab, loose fill powered type materials have appeared in the market. A good thermal insulation with suitable thickness would contribute to energy efficiency and economic operation of the cold storage. The most important characteristics of thermal insulation are high thermal resistivity and low temperature stability. The more the insulation on wall or ceiling of cold storage to make it energy efficient, the less is the heat gain means low refrigeration cost for saving in the cost of power or fuel required. A study undertaken by (Suman, 2012) with help of software TRNSYS shows that the better thermal insulation saves more cost of power than ordinary thermal insulation in AC building. Care must be taken therefore for cost of insulation and the capital cost of maintenance of the mechanical plant and determination of suitable thickness of insulation for required range of temperature. More than the recommended thickness of thermal insulation for maintaining the required temperature range is the wastage of money, therefore for cost saving, thermal insulation with suitable thickness should be used.

Modified Guarded Hot Plate Apparatus
Two specimen of size (300X300) mm are used in the Guarded Hot Plate apparatus as per IS: 3346 (1980), with thickness varying between 25mm to 50 mm for thermal conductivity measurement. These specimens are used between cold plate and the guarded hot plate. One specimen in between hot plate and cold plate placed at lower side of the hot plate and other specimen in between hot plate and cold plate above the hot plate. The principle of guarded hot plate apparatus states that the heat flows from guarded hot plate normal to the specimens to isothermal cold plate maintained at lower temperature. Two wooden

frames, identical in all respect have been fabricated for measurement of thermal conductivity of powdered material by (Suman, 2007) as per IS: 3346. Inner dimension of the frame is kept just equal to the specimen size (300X300X50) mm. The covers for open faces of the frame using blotting paper glued to the edges to the frame. The two frames were fabricated of thin walled with very low thermal conductivity having outside dimension larger than the specimen size. With one cover lying horizontally on flat surfaces on each frame filling with powder material to produce two specimen of equal and uniform density. The covered specimens are placed in the guarded hot plate apparatus, one between hot plate and lower cold plate and other above the hot plate and below the upper cold plate. The diagram of guarded hot plate apparatus is shown in photo 1.

Measurement of Thermal Conductivity of Powder Material

The temperature balance between the centre and guard sections of the main heaters which are separated by a small gap is maintained by using the output of the thermo couples to control the power supplied to the guard heater. The balance conditions can be checked by using the outputs of thermocouples pairs mounted in the surface plates on either side of the hot plates. The measuring theory of thermal conductivity of powder insulation is that when heat flow takes place normal to the specimen of unit thickness in unit time under steady state condition when temperature difference across the two opposite surfaces of the specimen is maintained as $1^{o}C$.

Density of the powder material is determined before placing it in the apparatus. Let us say the weight of the frame without powder material is W_1. Weight of the frame filled with the powder material is W_2. The net weight of powder material will be (W_2-W_1). Inner volume of the frame is (0.3X0.3X0.05) m^3. Therefore density of the powder material will be (W2-W1)/0.0045 kg/m^3. The detail diagram of frame and other parts of the guarded hot plate apparatus for measuring thermal conductivity of loose materials are shown in Figure 2.

As described in previous section the two frames filled with powder material is placed in the apparatus as specimens. Two cold plates are kept above and below the upper specimen and bottom specimen respectively. To increase the temperature of guard plate and central plate, power is supplied by controlled power supply and to maintain temperature in cold plates at set point, liquid at lower temperature is circulated in both the cold plates with the help of cryostat in which the liquid is maintained at lower temperature with help of compressor. When temperature of hot plate and cold plate are reached to set temperatures, the set temperature of hot plate is controlled and maintained by temperature controller. At one time, the temperature of the guard plate, central plate, and cold plates becomes constant and remain steady; it is assumed that the steady state heat flow condition has been reached. The power consumption and temperature difference of hot plate and cold plates is measured and thermal conductivity is determined by the equation,

$$K = \frac{\mathrm{V.I}}{\mathrm{A\nabla T}} \qquad \text{--- ---} \qquad \text{---} \qquad (1)$$

Where,
V- Voltage in Volt
I – Current in Ampere
d – Sample thickness in meter
A – Area of central hot plate
$\nabla -$ Difference in temperatures (^{o}C) of hot plate and cold plate

Thermal Conductivity Values

Number of powder materials has been undertaken for measurement of thermal conductivity values at mean temperature $30^{o}C$. The measured value of thermal conductivity of some solid and loose (powder) materials is given in Table 1.

Determination of Thickness

The amount and thickness of insulation shall be calculated on power savings in refrigeration, cost of insulation and to prevent surface condensation. For average climatic condition in India, the recommended thickness of insulation for various types of insulation material for cold storages are depending upon maximum overall thermal transmittance which is given in Indian codes (IS: 661, 2000). The recommended overall thermal transmittance values are shown in Table 2.

Table 1: Thermal conductivity of insulation materials

S. No.	Name of material	Thermal conductivity (W/m K)
1	EPS	0.036
2	PUF	0.023
3	Phenolic foam	0.026
4	Mineral wool/glass wool	0.033
5	Rice husk	0.051
6	Saw dust	0.074
7	Expanded perlite	0.039
8	Vermiculite	0.064

Table 2: For Max U-value (W/m^{2}k) as per IS: 661

Temperature range	Exposed wall	Intermediate wall	Roof	Floor
Temperature from -4^{o}C to 2^{o}C	0.267	0.581	0.244	0.290
Temperature from 2^{o}C to 10^{o}C	0.349	0.930	0.290	0.465

The calculation is followed by the Indian code (IS: 3792, 1978) insulation for non industrial types of buildings. Thickness of insulation depending upon U-value is computed by the given formulae,

$$L = K\,(1/U - (1/h_i - 1/h_o)) \qquad (2)$$

Where,
L is thickness in meter
K is thermal conductivity in W/m K
U is overall thermal transmittance in W/m^2 K
h_i and h_o are inside and outside surface heat transfer coefficient in W/m^2 K
The measured suitable thickness of powder insulation material satisfying the maximum U-value recommended by IS: 661 is given in table 3, 4, 5 and 6 respectively.

Table 3: Optimum thickness (m) for exposed wall

Temperature range	Expanded perlite	Fly ash	Vermiculite	Rice husk	Saw dust
Temperature from -4^{o}C to 2^{o}C	0.1399	1.5499	0.2296	0.1829	0.2655
Temperature from 2^{o}C to 10^{o}C	0.1056	1.1699	0.1733	0.1381	0.2004

Table 4: Optimum thickness (m) for intermediate wall

Temperature range	Expanded perlite	Fly ash	Vermiculite	Rice husk	Saw dust
Temperature from -4^{o}C to 2^{o}C	0.0616	0.6756	0.1000	0.0797	0.1157
Temperature from 2^{o}C to 10^{o}C	0.0358	0.3966	0.0587	0.0468	0.0679

Table 5: Optimum thickness (m) for roof

Temperature range	Expanded perlite	Fly ash	Vermiculite	Rice husk	Saw dust
Temperature from -4°C to 2°C	0.1537	1.7025	0.2522	0.2010	0.2916
Temperature from 2°C to 10°C	0.1283	1.4217	0.2106	0.1678	0.2435

Table 6: Optimum thickness (m) for floor

Temperature range	Expanded perlite	Fly ash	Vermiculite	Rice husk	Saw dust
Temperature from -4°C to 2°C	0.1283	1.4217	0.2503	0.1678	0.2435
Temperature from 2°C to 10°C	0.0777	0.8611	0.1275	0.1016	0.1475

Application Procedure

The powder insulation materials are applied in walls of the cold storage by making double walls and dropped into the space in between walls. Similarly the powder insulation is sandwiched between double roofing and double flooring systems so that heat flows do not take place from atmosphere or ground into the cold storage respectively. Such type of good powder thermal insulation is also used in annular space of cryogenic tank, LNG tank, Ammonia tank etc, by dropping the powder into the annular space of the tank to prevent heat flow.

RESULTS AND DISCUSSION

Table 3, 4, 5 and 6 consists of the respective optimum thicknesses of the powder insulation material for exposed wall, intermediate wall, roof and floor. These can be successfully utilized as replacement of conventional loose materials like rice husk or saw dust with comparatively lower thicknesses.

Figure 1: Photo of Automatic Guarded hot plate apparatus

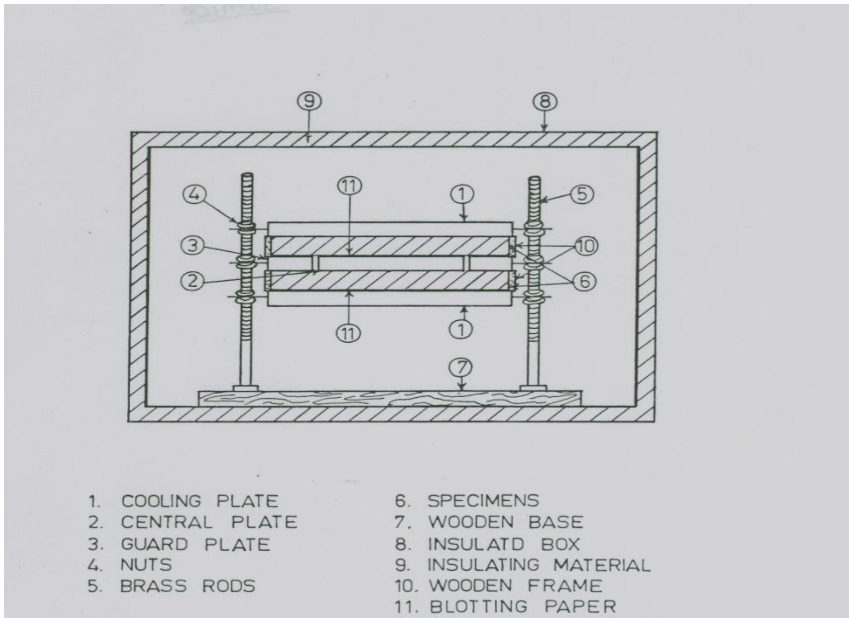

Figure 2: Diagram showing frame for measuring of k-value of loose material

Thermal conductivity of expanded Perlite is 0.039 W/m K. which is better than rick husk and wooden powder and at par with the EPS or Mineral wool. From thickness table it is found that the computed thickness to satisfy the recommended U-value by IS: 661 of expanded Perlite is 13.4 cm and for vermiculite it is 22.9 cm where indoor temperature of cold storage is maintained between -4 to 2^{o}C. By increasing the indoor temperature of cold storage, thickness is reduced to 10.6 cm and 17.3 cm thick expanded Perlite and vermiculite respectively. Similarly in case of rice husk and saw dust thermal insulation required thickness can be observed in table 2. It is found from the code IS:661 that thickness of Rice husk is higher than EPS, PUF, Phenolic foam and mineral wool which is being used currently. The expended Perlite thickness to maintain -4 to 2^{o}C for roof is 15.4 cm. We found from IS: 661, thickness of EPS is 14.2 which is slightly higher than expanded Perlite thickness to maintain -4 to 2^{o}C for roof. Similarly for all cases roof, wall for all temperature ranges -4 to 2^{o}C or 2 to 10^{o}C only higher marginal thickness in centimetre is required than EPS or mineral wool. The performance of PUF and Phenolic foam are quite better than other materials. Keeping cost in mind other thermal insulation along with performance wooden powder, Rice husk, Expanded Perlite and Vermiculite can also be used in the cold storage successfully.

Optimum thickness of powder materials are determined and it can be concluded form the result of that new powder thermal insulation like, expanded Perlite, vermiculite can replace conventional powder insulation like Rice husk and saw dust with lower thickness for making cold storage energy efficient. Thermal conductivity measurement of powder insulation material has been described in detail with Guarded hot plate apparatus as per IS: 3346 without any complexity.

ACKNOWLEDGMENT

The paper is sent for publication with permission of the Director, CBRI, Roorkee, India.

REFERENCES

Demirboga R and Gul R (2003). The effect of expanded perlite aggregate, silica fume and fly ash on the thermal conductivity of lightweight concrete. *Cement and Concrete Research* **33**(5) 723-727.

IS: 661(2000). Code of practice for thermal insulation cold storages. *BIS*.

IS: 3346(1980). Method for determination of thermal conductivity of thermal insulation material. *BIS*.

IS: 3792 (1978). Guide for heat insulation of non- industrial buildings. *BIS*.

Khan M, Prasad J and Suman BM (2008). Thermal properties of high volume fly ash concrete. *Indian Concrete Journal* **82**(5) 35-40.

Suman BM (2007). Thermal Conductivity Measurement of Loose Materials. *Proceedings of Modern Trends in Architecture and civil Engineering* (IE (India) Roorkee Chapter) 126-129.

Suman BM (2012). Energy Simulation for Sustainable Building with Application of Roof and Wall Insulation, *Proc National Conf Emerging Trends of Energy Conservation in Buildings.* (CSIR-CBRI, Roorkee) 360-369.

Suman O and Suman BM (2012). Thermal Insulation Materials for Energy Efficient Buildings. *Proceedings of National Conf Emerging Trends of Energy Conservation in Buildings* (CSIR-CBRI, Roorkee) 47-53.